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ABSTRACT

The term "equating" refers to a statistical procedure that adjusts test scores on different forms of the same examination so that scores can be interpreted interchangeably. This study examines the impact of equating with fewer items than originally planned when items have been removed from the equating set for a variety of reasons. A real data set from a licensure/certification examination was used for the study. Three linear equating methods and three test forms were involved. The sample size for each of the test forms was at least 10,000 examinees. Item sets were manipulated to discard different numbers of items. The scale scores computed using the decreased sets of equators were either unchanged or one point higher or lower than the scale scores computed using the original set of equators. The scale score fluctuations in nearly all of the decreased equating sets affected the passing scores of approximately two percent of the examinees, either increasing or decreasing the required scale score by one point. For a set in which two scale scores varied rather than just one, approximately four percent of the examinees were affected. Findings show that the equating plan designed for this examination was highly robust. (SLD)

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Effects of Decreasing the Number of Common Items in Equating Link Item Sets
Presented at AERA 2002, New Orleans

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Background

Equating is a statistical procedure that adjusts test scores on different forms of the same exam so that scores can be interpreted interchangeably. Equating enables comparisons of performance by different examinee groups, even though the groups were administered different forms of the test at different times. Many equating methods require exams to share a set of common items that are used for more than one administration. This common set of items provides statistical data to link the test forms for equating purposes.

Licensure and certification examinations often are equated using common item, non-equivalent groups design. Because the set of common items is used in multiple test forms, it is imperative that the items remain secure. If the examination is highly competitive, it is often difficult to prevent items from being compromised during a test administration. A related and equally difficult situation is when items must be discarded because they no longer represent the content specifications of the total test, or have become invalid due to changes in the body of knowledge. When the discarded items belong to the set of equating items, licensure and certification policy makers may seek psychometric advice to help make informed decisions about how to proceed.

Research Objective

The purpose of this study is to address practical problems related to common item sets used for equating. More specifically, the study examines the impact of equating with fewer items than originally planned when items have been removed from the equating set for a variety of reasons.

Researchers have examined the effect of the number of common items on the accuracy of equating. Kolen and Brennan (1995) stated that "the number of common items to use should be considered on both content and statistical grounds" (pp. 248). Klein and Jarjoura (1985) compared content representative sets of common items with larger sets of common items that were not content representative. They found that content representativeness of common item sets was "critical" to equating accuracy and concluded that the longer, non-representative common item sets produced less accurate equating results. Harris' study (1991) later supported this conclusion. Gao, Hanson and Harris (1999) examined the effect of content and statistical non-representativeness on common item equating with non-equivalent groups. They found that content itself did not greatly impact equating results. However, if the common item set was not statistically representative, a content representative common item set may produce less equating error than a content non-representative set.

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The present study was designed to examine the effect of diminishing content and statistical representativeness of common item sets relative to an original common item set when equating with two link forms. The focus was to provide useful information to persons in charge of testing programs confronted with the very real situation of what to do when equating items have been compromised. The outcomes of the study should provide guidance for how to proceed when test forms have been lost, breached or equating items discarded for other reasons. The study investigated:

- The effects of discarding 5 and 10 items from a set of 30 common items;
- The effects of discarding items that result in the common item set reflecting less accurately the statistical specifications of the total test;
- The effects of discarding items that result in the common item set reflecting less accurately the content areas of the total test.

Methodology

A real data set from a licensure/certification examination was used for this study. The exam consisted of 200 total items including 60 common items, ten for each of six content areas. The common items were divided evenly between two link exam forms with each form providing 30 items, 5 for each content area. When exams have been compromised in the past, typically only one of the two link exam forms has been affected. Therefore, for this study items were discarded from only one link form rather than both.

Three linear equating methods were used (Tucker, Levine Observed Score, and Levine True Score) and three test forms were involved; one new form and two equating link forms. Sample size for each of the three test forms was ten thousand examinees, or more. The same data sets and equating methods were used for the various conditions under which items were discarded from the common item set.

The equating results using the full set of common items provided baseline data that were compared with results using sets of common items from which items were discarded. Twelve common item sets were manipulated: six sets discarded five equators from each set (8% of the total number of common items) and six sets discarded ten equators from each set (17% of the total number of common items). Discarded items were included in the computations for whole test results, but were excluded from the computations for the common item equating set.

When items would be removed from an equating set, obviously the overall characteristics would change for the entire item set. Although many characteristics of the decreased item sets could be studied, this research focused on examining changes in the following areas:

- Scale score moments;
- Conversion of raw scores to scale scores within the range of passing scores;
- Standard error of equating within the range of passing scores.

Study Design

Tables 1 and 2 list the general characteristics of the total test, the original item set, and the decreased item sets. Table 1 shows the characteristics of the common item sets that

were decreased by five equators, and Table 2 shows the characteristics of the common item sets decreased by 10 equators. The first column displays the characteristics of the total test followed by the original equating set of 30 items from one link form. The average difficulty (p-value) and standard deviation (SD) is displayed for each of the six content areas. The remaining columns show characteristics of the item sets from which equators were discarded.

Note that each decreased item set was manipulated with regard to the degree of representation of the six content areas and the level of item difficulty. In the past when items have been compromised, typically the items have represented different content areas rather than the same area. Consequently, for this study items were discarded from more than one content area rather than from only one content area.

Differences between the original equating set and the decreased equating sets can be identified by comparing the number of items in the set and the average item difficulty by content area. In addition, the characteristics of the common item sets can be compared with the characteristics of the total test by content areas.

Given the relatively small number of items discarded from each set, the content representation and average level of item difficulty could vary only moderately for each decreased equating set. Working within these limitations, items were discarded from one link form to create equating sets with the following characteristics:

Level of content representation for decreased common item sets

Content representation – items were discarded from content areas somewhat equally across all content areas

- 5 items were discarded – Sets A, B
- 10 items were discarded – Sets G, H

Content non-representation – items were discarded from content areas somewhat unequally across all content areas

- 5 items were discarded – Sets C, D, E, F
  Most items were discarded from only two of the six content areas
- 10 items were discarded – Sets I, J, K, L
  Most items were discarded from only three of the six content areas

Level of statistical representation for decreased common item sets

Statistical representation – p-values were approximately the same for the original and decreased sets of common items

- Level of difficulty by content area was similar to the level of difficulty for the original equating set

Statistical non-representation – p-values varied somewhat for the original set and decreased set of common items

- Some content areas were more difficult than the original equating set
- Some content areas were less difficult than the original equating set

Table 1
Characteristics of Total Test, Original Equating Set and Decreased Equating Sets
(Discard 5 items in each set)

	Total Test 200 items	Original Set 30 items	Set A 25 items	Set B 25 items	Set C 25 items	Set D 25 items	Set E 25 items	Set F 25 items
Number of common items by content areas I - VI	I	5	3	5	3	5	4	5
	II	5	4	4	5	2	3	5
	III	5	4	5	5	3	3	2
	IV	5	5	3	4	5	5	5
	V	5	4	4	5	5	5	3
	VI	5	5	4	3	5	5	5
Mean p-value and (SD) by content areas I - VI	I 0.674 (.179)	.670 (.173)	.646 (.185)		.552 (.086)		.721 (.150)	
	II 0.537 (.189)	.560 (.131)	.555 (.151)	.539 (.141)		.430 (.055)	.647 (.068)	
	III 0.551 (.204)	.526 (.172)	.535 (.198)			.415 (.091)	.626 (.136)	.693 (.100)
	IV 0.613 (.154)	.617 (.187)		.594 (.256)	.550 (.128)			
	V 0.585 (.173)	.573 (.104)	.573 (.121)	.546 (.099)				.642 (.059)
	VI 0.662 (.187)	.664 (.199)		.686 (.223)	.571 (.204)			
Changes in decreased equating sets relative to original set			Same difficulty; content representative	Same difficulty; content representative	More difficult; content non-representative	More difficult; content non-representative	Less difficult; content non-representative	Less difficult; content non-representative

Table 2
Characteristics of Total Test, Original Equating Set and Decreased Equating Sets
(Discard 10 items in each set)

	Total Test 200 items	Original Set 30 items	Set G 20 items	Set H 20 items	Set I 20 items	Set J 20 items	Set K 20 items	Set L 20 items
Number of common items by content areas I - VI	I	5	3	4	1	5	4	2
	II	5	4	3	5	3	2	5
	III	5	4	2	5	1	2	5
	IV	5	3	3	2	5	5	1
	V	5	2	4	5	1	2	2
	VI	5	4	4	2	5	5	5
Mean p value and (SD) by content areas I - VI	I 0.674 (.179)	.670 (.173)	.646 (.185)	.628 (.168)	.466 (xxx)*		.721 (.151)	.847 (.016)
	II 0.537 (.189)	.560 (.131)	.555 (.151)	.525 (.170)		.480 (.096)	.680 (.052)	
	III 0.551 (.204)	.526 (.172)	.535 (.198)	.557 (.092)		.315 (xxx)*	.693 (.100)	
	IV 0.613 (.154)	.617 (.187)	.691 (.202)	.571 (.147)	.448 (.052)			.887 (xxx)*
	V 0.585 (.173)	.573 (.104)	.514 (.085)	.573 (.121)		.454 (xxx)*	.677 (.005)	.677 (.005)
	VI 0.662 (.187)	.664 (.199)	.647 (.226)	.611 (.185)	.568 (.289)			
Changes in decreased equating sets relative to original set			Same difficulty; content representative	Same difficulty; content representative	More difficult; content non-representative	More difficult; content non-representative	Less difficult; content non-representative	Less difficult; content non-representative

*SD is not calculated because the common item set contained only one item for the content area.

Findings

The raw scores for the exam under investigation ranged from 1 to 200. For reporting purposes, the raw scores were linearly converted to scale scores that ranged from 0 to 200. Different equating methods were used to analyze the data, and all methods produced very similar results when compared with the original outcomes. Therefore, the results reported are based on one equating method rather than reporting results from all the equating methods used.

Table 3 lists the scale score moments of the original set of common items and the 12 decreased common item sets. Also listed are the standard deviation, skewness, and kurtosis measures for each equating set. In general, regardless of the number of items discarded, the scale score moments from each set were quite similar to the original results. The extent to which the sets were content and statistically non-representative did not influence the results.

No universal passing score was established for the exam program being analyzed. For the purpose of the study, several passing scores were considered within the range of 130 and 135 scale score points. Of primary interest were the variations in the scale scores produced by the decreased common item sets within the range of passing scores. The most notable finding of the study is the small difference, if any, in the scale scores produced using the original set of 30 common items and those using sets decreased by either 5 or 10 items. Tables 4 and 5 compare differences in scale scores within the range of passing scores for the original equating set and the twelve decreased equating sets.

The scale scores computed using the decreased sets of equators were either unchanged, or one point higher or lower than the scale scores computed using the original set of equators. Of the 84 total scale scores computed under the twelve conditions (7 passing scores x 12 reduced equator sets) 74 scores remained the same as the original scale score, 8 scores increased by one point, and 2 scores decreased by one point. The equating sets that discarded five items produced four scale scores that differed from the original scale scores (three scores +1 and one score –1). The equating sets that discarded ten items produced six scale scores that differed from the original scale scores (five scores +1 and one score –1).

The scale score fluctuations in nearly all of the decreased equating sets affected the passing scores of approximately 2% of the examinees, either increasing or decreasing the required scale score by one point. For equating set G, approximately 4% of the examinees were affected because two scale scores varied rather than just one.

Discrepancies in scale scores could be the result of changes in the overall level of difficulty of the decreased equating sets relative to the mean difficulty level of the original equating set. Note that the level of difficulty (p-value) of the decreased equating sets was manipulated to modestly increase, decrease, or remain about the same as the original equating set. However, no pattern appeared in the scale scores that could be associated with the effect of varying the level of difficulty of the decreased equating sets.

In addition, the representation of the content areas of the decreased equating sets was manipulated to produce somewhat representative or non-representative sets. Again, no patterns appeared in the scale scores that could be associated with the effect of varying the content representation of the decreased equating sets.

Sampling error also could have caused variations in outcomes such that scale scores would differ slightly, depending upon the sample analyzed. Variations in scale scores were so small, however, that equating with a variety of recommended equating methods using the original common item set produced fluctuations that were similar to results using the decreased equating sets.

The standard error of equating (SEE) is an index that estimates the amount of random error in the equating process. Kolen and Brennan (1995) wrote a detailed summary of SEE calculation for different equating design, one of which was implemented for the study. Tables 6 and 7 show the SEE estimates when different sets of common items were used. Error estimates near the passing scores are of primary interest. Note the small difference in equating error estimates between those scores computed using the original set of equators and those using the decreased sets of equators. As would be expected, equating error estimates were lowest when using 30 items and increased slightly when using fewer items. Once again, the effect of content and statistical non-representativeness did not influence SEE. Differences in SEE were quite small and within the range typically reported for various administrations of the examination.

Table 3
Scale Score Moments of Original Equating Set and Decreased Equating Sets

Set of Common Items	Mean Scale Score	Standard Deviation	Skewness	Kurtosis
Original Set	136.616	15.362	-0.144	2.984
Discard 5 Items				
Set A	136.678	15.330	-0.146	2.984
Set B	136.769	15.364	-0.144	2.984
Set C	136.616	15.362	-0.144	2.984
Set D	136.386	15.365	-0.143	2.983
Set E	136.610	15.390	-0.145	2.989
Set F	136.703	15.378	-0.140	2.986
Discard 10 Items				
Set G	136.858	15.302	-0.146	2.985
Set H	136.693	15.360	-0.144	2.985
Set I	136.616	15.362	-0.144	2.984
Set J	136.395	15.349	-0.140	2.980
Set K	136.775	15.403	-0.143	2.983
Set L	136.702	15.381	-0.141	2.989

Table 4
Scale Scores within the Range of Passing Scores
Comparison of Original Equating Set with Decreased Equating Sets
(Discard 5 items in each set)

Raw Scores			Scale Scores						
% Pass	% Fail	Original Set Raw Score	Original Set Scale Score	Set A	Set B	Set C	Set D	Set E	Set F
68.59	31.41	120	130	130	130	130	130	130	130
66.53	33.47	121	131	131	131	131	130 -1	131	131
64.45	35.55	122	131	132 +1	132 +1	131	131	131	132 +1
62.37	37.63	123	132	132	132	132	132	132	132
60.26	39.74	124	133	133	133	133	133	133	133
58.13	41.87	125	134	134	134	134	134	134	134
56.11	43.89	126	135	135	135	135	135	135	135
Number of scale scores that increased or decreased by one scale point				**+1**	**+1**	**0**	**-1**	**0**	**+1**
Percent of examinees affected by change in passing scale scores				**2.08%**	**2.08%**	**0%**	**2.06%**	**0%**	**2.08%**

Table 5
Scale Scores within the Range of Passing Scores
Comparison of Original Equating Set with Decreased Equating Sets
(Discard 10 items in each set)

Raw Scores			Scale Scores						
% Pass	% Fail	Original Set Raw Score	Original Set Scale Score	Set G	Set H	Set I	Set J	Set K	Set L
68.59	31.41	120	130	130	130	130	130	130	130
66.53	33.47	121	131	131	131	131	130 -1	131	131
64.45	35.55	122	131	132 +1	132 +1	131	131	132 +1	132 +1
62.37	37.63	123	132	133 +1	132	132	132	132	132
60.26	39.74	124	133	133	133	133	133	133	133
58.13	41.87	125	134	134	134	134	134	134	134
56.11	43.89	126	135	135	135	135	135	135	135
Number of scale scores that increased or decreased by one scale point				**+2**	**+1**	**0**	**-1**	**+1**	**+1**
Percent of examinees affected by change in passing scale scores				**4.16%**	**2.08%**	**0%**	**2.06%**	**2.08%**	**2.08%**

Table 6
Standard Error of Equating (SEE) within the Range of Passing Scores
Comparison of Original Equating Set with Decreased Equating Sets
(Discard 5 items in each set)

Raw Scores			Standard Error of Equating Estimates						
% Pass	% Fail	Original Set Raw Score	Original	Set A	Set B	Set C	Set D	Set E	Set F
68.59	31.41	120	0.116	0.123	0.125	0.123	0.122	0.123	0.124
66.53	33.47	121	0.113	0.121	0.122	0.121	0.120	0.120	0.121
64.45	35.55	122	0.111	0.119	0.120	0.118	0.118	0.118	0.120
62.37	37.63	123	0.109	0.117	0.118	0.116	0.116	0.117	0.118
60.26	39.74	124	0.108	0.115	0.116	0.114	0.114	0.115	0.117
58.13	41.87	125	0.106	0.113	0.115	0.112	0.112	0.114	0.115
56.11	43.89	126	0.105	0.112	0.113	0.111	0.111	0.113	0.114

Table 7
Standard Error of Equating (SEE) within the Range of Passing Scores
Comparison of Original Equating Set with Decreased Equating Sets
(Less 10 items in each set)

Raw Scores			Standard Error of Equating Estimates						
% Pass	% Fail	Original Set Raw Score	Original	Set G	Set H	Set I	Set J	Set K	Set L
68.59	31.41	120	0.116	0.131	0.129	0.134	0.132	0.132	0.133
66.53	33.47	121	0.113	0.129	0.126	0.131	0.130	0.130	0.131
64.45	35.55	122	0.111	0.127	0.124	0.129	0.128	0.128	0.129
62.37	37.63	123	0.109	0.125	0.122	0.126	0.126	0.126	0.127
60.26	39.74	124	0.108	0.123	0.120	0.124	0.124	0.125	0.125
58.13	41.87	125	0.106	0.122	0.119	0.122	0.123	0.124	0.124
56.11	43.89	126	0.105	0.121	0.118	0.121	0.121	0.123	0.122

Conclusions

The purpose of this study was to use "real" data to examine the impact of equating with fewer items than required by a predetermined equating plan. The study was designed to examine the effect on reported scores of equating with sets of common items that were smaller and less representative of the content and difficulty level than the original, optimal set of common items. The most notable finding was the small difference, if any, in the scale scores produced using the original set of common items and those using sets decreased by 5 and 10 items.

Findings suggest that the equating plan designed for this particular licensure/certification examination was highly robust. The equating design, which used 2 link forms with 30 common items from each link, provided an adequate pool that withstood the impact of discarding 5 and 10 items from one link. The design seemed to create a buffer that produced satisfactory equating results under less than optimal conditions, such as those caused by security breaches and content changes.

The effects of varying numbers of items discarded from the common item set. Equating with five and ten fewer items than the original 60 common items seemed to have affected scale scores only slightly. Some scale scores remained unchanged, while other scores increased or decreased by only one point. Evidence based on the scale score moments support the consistency of scale scores across the common item sets. The number of discarded items had minimal impact on the resulting standard error of equating and was within the range of SEE typically exhibited in multiple administrations of the exam. The standard error of equating remained reasonable, although it was slightly higher when using common item sets from which equators were discarded, when compared with SEE using the original common item set.

The effects of discarding items that result in the common item set reflecting less accurately the statistical specifications of the total test. Findings suggest that equating with a set of common items that does not exactly reflect the level of item difficulty of the total test has minimal impact on the resulting scale scores.

The effects of discarding items that result in the common item set reflecting less accurately the content areas of the total test. Findings suggest that equating with a common set of items that does not equally represent the content areas of the total test has minimal impact on the resulting scale scores.

The findings from this study are consistent with results from Gao, Hanson and Harris (1999), which showed that content non-representativeness for the common item set did not influence equating accuracy. Moreover, results from this study showed that statistical non-representativeness did not greatly influence the equating results, though larger numbers of discarded items increased equating error.

Pass/fail decisions for high stakes licensure and certification examinations usually require multiple types of evaluation. Consequently, a one-point fluctuation in the scale score of one examination that is combined with scores from other assessments most likely would

have minimal impact on the overall pass/fail rate. However, if scores from multiple forms of evaluation were scaled to the examination under study, the impact of a one-point fluctuation in the scale score could be compounded.

The results of this study suggest that when an equating plan is well designed, the equating process can withstand discarding compromised items without severely jeopardizing exam results. The fact that the equating design and methodology appears robust suggests that more complicated procedures, such as weighting the remaining items to obtain content representativeness, might not be necessary. Obviously, dramatic events could produce profound consequences on equating outcomes, but experiences to date would realistically suggest that discarding a limited number of common items is the most extreme consequence of managing compromised items. This finding should be reassuring to those in charge of operational testing programs that implement a well-constructed, double link equating design.

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